Thermophysical properties of ceramic materials based on SiC-AlN solid compounds.

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Introduction

Ceramics materials on the basis of solid solutions in the SiC-AlN system have a great practical value [1]. It is connected with their thermostability and chemical stability to oxygen gas media. It is known that in this system constant solid compounds are formed [2] and SiC-AlN system state data [3] show that the components should dissolve equally mutually along with formation of different polytypes.

Few works are dedicated to the analysis of heat and physical and mechanical characteristics of ceramics on SiC-AlN basis though heat conductivity of silicon carbide and of aluminium nitride has been analyzed well.

This work analyses temperature and concentration dependences of heat conductivity (λ), thermal expansion coefficient (α) (TEC), isobaric specific heat capacitance (C_p), and elastic (longitudinal (υ_l) and transversal (υ_t)) velocity of ultrasonic waves, Young's modulus (E), dilatation of maltilateral compression (B), shift (G), Poisson's ratio (μ), properties of ceramics materials based on $(SiC)_{1-x}(AlN)_x$ solid compounds have been measured.

Experiment.

To obtain $SiC)_{1-x}(AlN)_x$ ceramics silicon carbon and plasmachemical aluminium nitride of 1 mcm dispersion were used, which were mixed up in the following proportions (x=0.1, 0.3, 0.5, 0.7, 0.9). Before the caking process powders of SiC and AlN were activated $(SiC)_{1-x}(AlN)_x$ ceramics was obtained by heat pressing methodics at temperature 2120 – 2320 K, heat pressure up to 35 MPa. It was accomplished in N_2 medium during 1 hour. Density of the obtained

polycrystal solid solutions $(SiC)_{1-x}(AlN)_x$ was determined by the method of hydrostatic weighing. Obtained $(SiC)_{1-x}(AlN)_x$ ceramics structures were analyzed according to integral intensity of x-ray Cu $_{K\alpha}$ on the difractometer DRON-2,0 at accelerating power 20 kV.

Heat and physical properties in polycrystal solid compounds $(SiC)_{1-x}(AlN)_x$ were analyzed both stationarily and in the unit of the flat temperature waves [4]. The samples for analysis of heat and physical properties were discs with diameter – height correlation d/L=4. Heat expansion coefficient (HEC) was measured by the quartz dilatometer [5] with the use of beam forms of 5x5x70 mm. Error in measurements was not more than 4%.

Elasticity modules were calculated according to the measured values of density and the rates of longitudinal (υ_l) and transverse (υ_t) ultrasound waves. The ultrasound rate was measured by the impulse and resonance methods. Impulse measurements were obtained by the acoustic tester [6] in "passing" mode at frequency 5 MGh. The bending and radial fluctuation frequencies of discs were measured by [7]. Rates υ_l a υ_t were calculated by these frequencies. Discs of 20-40 mm diameter and 7 mm of thickness were used.

Results and discussion.

X-ray and structural analysis of the obtained results of polycrystalic solid solutions $(SiC)_{1-x}(AlN)_x$ have shown the change of constant grate "c" proving solid solutions formation. It is supposed that aluminium preferably replaces silicon atoms because Al radius is closer to Si radius than C. Correspondingly, potential energy of the elastic deformation is best than in case of C substitution. Moreover with silicon substitution by aluminium, the latter forms binary composition Al_4C_3 with more stable bounds than in tetrahedron coordination carbon atoms.

Aluminium nitride influences the polytype composition SiC. Samples with little AlN (≤30% of weight) had mainly 15R and 6H polytypes, but with AlN concentration of 50 % of weight 4H, 2H and seldom 8H were observed.

Analysis of polycrystal solid compounds $(SiC)_{1-x}(AlN)_x$ grain structure has shown that AlN leads to formation of fine – grained structure of 2 – 8 mc. Such

structure is preserved at heat up to 2520 K. And with growth of AlN composition SiC grain size is lessened. Data on heat and physical and elastic parameters at T=300 K are shown in table 1.

Table 1.

Parameter	Composition, ***x***				
	0.1	0.3	0.5	0.7	0.9
Heat conductivity, λ, Wt/(mK)	42.8	29.1	24.3	19.4	14.7
Thermal expansion coefficient, α 10^{-6}/K	2.8	3.31	3.68	4.1	4.5
Specific heat at constant pressure C_p, J/kg*K	680	693	701	711	723
Velocity of longitudinal ultrasonic waves, v_l, m/s	11440	11150	10870	10630	10260
Velocity of transvers ultrasonic waves, v_t, m/s	7230	7020	6630	6300	5920
Deby temperature, Θ, K	1170	1115	1058	1010	966
Young's modulus, E, GPa	390	377	349	321	288
Gruneisen parameter, γ	0.65	0.69	0.73	0.84	0.88
Poison's ratio, μ	0.13	0.14	0.21	0.22	0.26
Bulk modulus, B, GPa	188	189	192	195	202
Shear modulus, G, GPa	193	171	152	131	115
Density, ρ, kg/m^3	3.16	3.212	3.217	3.221	3.223
Polytype	6H, 15R	6H, 15R	2H, 4H	2H, 4H,8H	2H

Table 1 shows that sample density in the compounds from 30 % to 90 % of AlN weight is practically constant and is a theoretical density which shows the samples macrostructure unchangeability and high stability of their obtaining.

It is seen on the SiC, $SiC_{0.5}AlN_{0.5}$, AlN ceramics thermoconductivity temperature dependence curves that heat conductivity of ceramics on the basis of SiC-AlN solid solution falls with growth of AlN concentration (Fig.1).

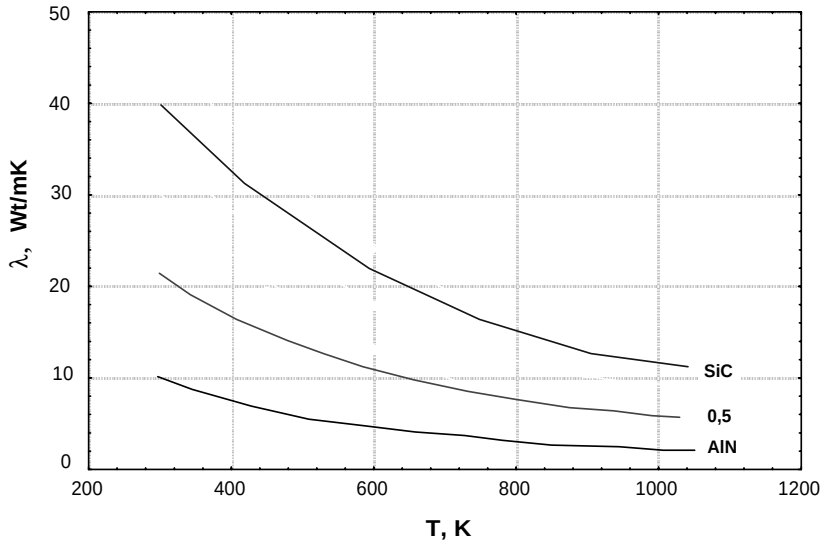

Fig.1. Temperature dependence of heat conductivity (SiC, $SiC_{0,5}$-$AlN_{0,5}$, AlN).

Fall in heat conductivity of SiC and AlN is explained by the growth of disharmonic heat fluctuations of SiC and AlN and by the weakened inter atomic ties. This is shown by the linear growth of TEC too (Fig.2).

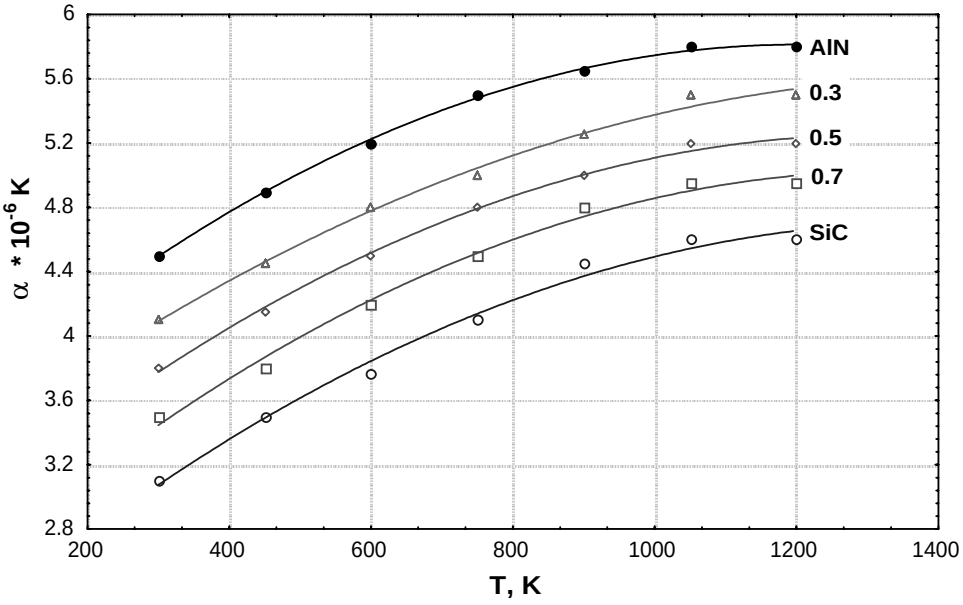

Fig.2. Temperature dependence of TEC $(SiC)_{1-x}(AlN)_x$.

Fig. 3 shows isotherms of concentration dependence of Young ceramics module on the basis of $(SiC)_{1-x}(AlN)_x$ polycrystal solid solutions.

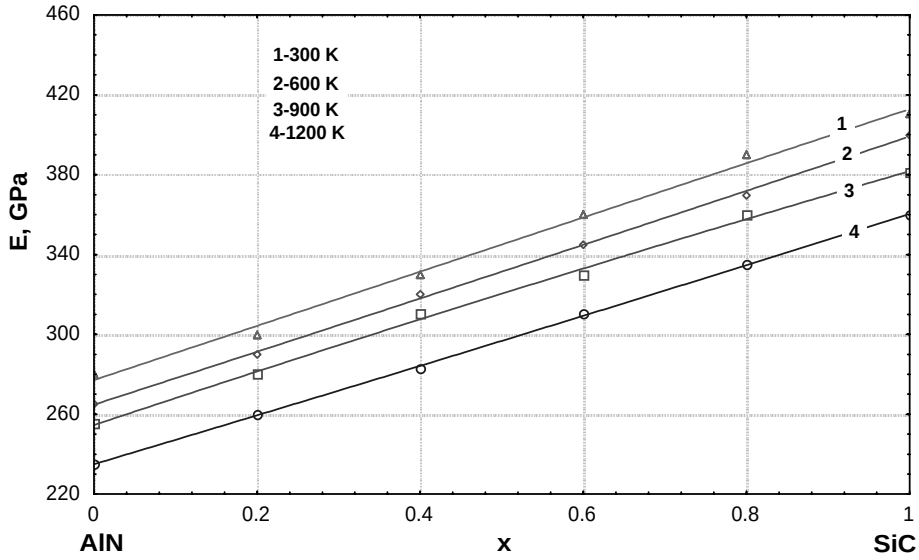

Fig. 3. Isotherms of concentration dependence of Young's modulus $(SiC)_{1-x}(AlN)_x$.

Our data according to Young's modulus satisfactorily agree to the data obtained by statistic method [8] and its minimal difference is explained by the ultrasound waves speed dispersion. Dependence of $(SiC)_{1-x}(AlN)_x$ elasticity modules on AlN composition is practically linear.

Conclusion.

By way of caking fine-dispersive powders of silicon carbon and aluminium nitride homogeneous polycrystal solid solutions $(SiC)_{1-x}(AlN)_x$ have been obtained. It`s found that with growth of AlN in ceramics based on $(SiC)_{1-x}(AlN)_x$ solid solutions polytype 2H is stabilized, and the structure becomes fine-grained. With growth of temperature and AlN heat-conductivity and Young's modulus decrease but TEC increases.

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